Centers for Disease Control and Prevention
Epidemiology Program Office
Division of Public Health Surveillance and Informatics

Annotated Bibliography for Syndromic Surveillance

What is syndromic surveillance?
The term "syndromic surveillance" applies to surveillance using health-related data that precede diagnosis and signal a sufficient probability of case or an outbreak to warrant further public health response. Though historically, syndromic surveillance has been utilized in situations where resources are to target investigation of potential cases, its utility for detecting outbreaks associated with bioterrorism is increasingly being explored by public health.

Purpose of this annotated bibliography
The purpose of this annotated bibliography is to provide an information resource addressing syndromic surveillance associated with bioterrorism. The primary audiences are public health practitioners who want to learn more about syndromic surveillance and/or systems or who have a system that they want to improve upon.

We attempted to gather key articles on syndromic surveillance associated with bioterrorism. Resources included in this bibliography are peer-reviewed articles, academic papers, technical reports, and Web-based information on syndromic surveillance systems. The resources are categorized by the following groupings: overview/general, analytic methods, informatics, evaluation of syndromic surveillance systems, and other resources. In addition, non-bioterrorism-related resources include information on syndromic surveillance not addressing bioterrorism but which may still be of use to our audiences.

We hope this bibliography will help to facilitate discussions about the strengths and weakness of syndromic surveillance and help identify future research needs in this emerging field. Since this annotated bibliography on syndromic surveillance is a work in progress, we welcome suggestions and comments on:

1) ***Format of this web resource,***
2) ***Reviews of articles, and***
3) ***Additional references/resources not included in the bibliography.***

Please direct these suggestions and comments to framework@cdc.gov.

Methods

Resources were derived from a variety of sources. First, a Pub Med search was conducted to find published peer-reviewed literature. The search strategy utilized the following key words in varying combinations: syndromic surveillance, bioterrorism, early detection outbreak, pre-diagnosis surveillance, non-traditional surveillance, enhanced surveillance, drop-in surveillance, health indicator surveillance, and disease early warning systems. Second, a search was conducted on Internet search engines (e.g., Google) to find non-peer-reviewed reports, (e.g., technical reports, abstracts, conference papers, etc.) and websites addressing syndromic surveillance. The type of resource is indicated after each citation for non-journal resources.

Limitations and Disclaimer

This bibliography is meant as an information-gathering resource on syndromic surveillance and systems for public health practitioners. The resources included have only been briefly summarized and are not intended to be an exhaustive bibliography. We will periodically update the bibliography with current and relevant resources. Finally, the inclusion of the names of any specific products or companies in this annotated bibliography does not constitute an endorsement by the Centers for Disease Control and Prevention.

A. Overview/General

1. Bioterrorism Preparedness and Response: Use of Information Technologies and Decision Support Systems. Summary, Evidence Report/Technology Assessment: Number 59, July 2002. Agency for Healthcare Research and Quality, Rockville, MD. (http://www.ahrq.gov/clinic/epcsums/bioitsum.htm)

   The Evidence Report details the methodology, results, and conclusions of a systematic and extensive search for published materials on the use of information technology and decision support systems to serve the information needs of clinicians and public health officials in the event of a bioterrorist attack. The information is intended to assist clinicians, public health officials, and policymakers to improve preparedness for a bioterrorism event.

2. Duchin JS**.** Epidemiological Response to Syndromic Surveillance Signals. Journal of Urban Health 2003 80: i115-i116.

   This brief article describes a process of confirming and validating the syndromic surveillance signals before initiating a public health response.

3. Green MS, Kaufman Z. Surveillance for early detection and monitoring of infection disease outbreaks associated with bioterrorism. Israel Medical Association Journal 2002 Jul; 4(7): 503-6.

   This paper provides a brief overview of surveillance for bioterrorist initiated outbreaks and provides a few examples of syndromic surveillance systems, both internet and non-internet based surveillance information systems.

4. Henning KJ. Syndromic Surveillance. In Institute of Medicine 2003. Microbial Threats to Health: Emergence, Detection, and Response. Ed. Smolinski MS, Hamburg MA, Lederberg

J. The National Academies Press, Washington, DC. 309-350. (http://www.iom.edu/report.asp?id=5381)

This appendix chapter provides an overview of syndromic surveillance systems to enhance the detection of emerging infections and illness due to bioterrorism agents. The paper provides definitions and rationale, surveillance system attributes, types of syndromic surveillance systems, cost-effectiveness data if available, and key steps in development of syndromic surveillance systems.

5. Lober WB, Karras BT, Wagner MM, Overhage JM, Davidson AJ, Fraser H, Trigg LJ, Mandl KD, Espino JU, Tsui FC. Roundtable on bioterrorism detection: information system-based surveillance. Journal of the American Medical Informatics Association 2002 Mar-Apr; 9(2): 105-15. (http://www.jamia.org/cgi/content/full/9/2/105)

   The Roundtable on Bioterrorism Detection was hosted during the 2001 AMIA annual Symposium, and its goal was to foster communication and cooperation about researchers in an effort to increase the pace of research and system deployment. This paper combines case reports of six existing systems with discussion of some common techniques and approaches for early detection of outbreaks.

6. Mostashari F, Hartman J. Syndromic surveillance: a local perspective. Journal of Urban Health 2003; 80 Suppl 1:i1-i7.

   This paper provides a perspective on some of the key tensions and challenges facing the field of syndromic surveillance. Some of the issues include traditional versus nontraditional data sources, analytic approaches, evaluation, investigation of signals, security versus civil liberties, national versus local, and the dual use of these systems for bioterrorism and non-bioterrorism related research.

7. Muhm JM, Karras BT. Syndromic surveillance. Aviation, Space, and Environmental Medicine 2003 Mar;74 (3):293-4.

   This article briefly discusses the societal, technical, and analytical challenges of syndromic surveillance.

8. Pavlin JA. Investigation of Disease Outbreaks Detected by "Syndromic" Surveillance Systems. Journal of Urban Health 2003; 80: i107-i114.

   This article describes the steps of disease outbreak investigation to syndromic surveillance signals: confirm existence of outbreak, verify diagnosis, estimate the number of cases, orient to person, place, and time, develop and evaluate hypothesis, implement control measures, and communicate findings. Examples of outbreaks detected by an electronic surveillance system are described.

9. Platt R, Bocchino C, Caldwell B, Harmon R, Kleinman K, Lazarus R, Nelson A, Nordin JD, Ritzwoller. Syndromic surveillance using minimum transfer of identifiable data: the example of the National Bioterrorism Syndromic Surveillance Demonstration Program. Journal of Urban Health 2003; 80 Suppl 1:I25-I31.

   This paper presents a brief description of a surveillance system that relies principally on reporting by health plans to public health agencies of aggregated (count) data, rather than

on reporting of encounter-level data, and it discusses the reasons for adopting this method of data-sharing for syndromic surveillance.

10. Reingold A. If syndromic surveillance is the answer, what is the question? Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science 2003; 1(2): 1-5.
    This policy paper analyzes some of the underlying assumptions put forward in support of syndromic surveillance, and the author urges closer scrutiny of these assumptions before investing scarce public health resources. Assumptions include: reducing morbidity/mortality following a bioterrorist attack; types of bioterrorists events detected; responding to increases signaled by syndromic surveillance, increased timely identification of population at risk; providing useful information about naturally occurring infectious disease, and strengthening local and state health departments.

11. Syndromic surveillance. Healthcare Hazard Management Monitor. 2003 Apr;16(8):1-6.
    This article provides an overview of syndromic surveillance, as compared to traditional public health surveillance, discussing healthcare involvements, challenges and limitations of syndromic surveillance.

12. Teich JM, Wagner MM, Mackenzie CF, Schafer KO. The informatics response in disaster, terrorism, and war. Journal of the American Medical Informatics Association 2002 Mar-Apr; 9(2): 97-104. (http://www.jamia.org/cgi/content/full/9/2/97)
    The paper presents an overview of bioterrorism, mass disasters, and remote military operations and discusses the ongoing work of experts who began working on these problems before the current national crisis. Included in the bioterrorism section is a discussion of the need for real time surveillance and examples of early warning systems for outbreak detection.

13. Wagner MM, Tsui FC, Espino JU, Dato VM, Sittig DF, Caruana RA, McGinnis LF, Deerfield DW, Druzdzel MJ, Fridsma DB. The emerging science of very early detection of disease outbreaks. Journal of Public Health Management Practice 2001 Nov; 7(6): 51-9.
    The authors identify and review mathematical foundations of early detection and review the literature on defining timeliness requirements for specific threats and on measuring the timeliness of specific detection systems for specific threats.

14. Zeng X, Wagner M. Modeling the effects of epidemics on routinely collected data. Journal of the American Medical Informatics Association. Proceedings AMIA Symposium 2001;:781-5. (http://dev.health.pitt.edu/ahrq/restricted/papers/AMIA%20Behavior.doc)
    The authors reviewed studies in behavioral medicine and health psychology in order to build a model linking known factors related to human health information and treatment seeking behavior and effects on routinely collected data (e.g., absenteeism). A model of patient behavior after a bioterrorism attack is provided.

B. Analytic Methods

- **Data Sources and Case Definition**

1. Begier EM, Sockwell D, Branch LM, Davies-Cole JO, Jones LH, Edwards L, Casani JA, Blythe D. The National Capitol Region's emergency department syndromic surveillance system: do chief complaint and discharge diagnosis yield different results? Emerging Infectious Disease 2003 Mar; 9(3): 393-6.
   The paper compared syndromic categorization of chief complaint and discharge diagnosis for 3,919 emergency department visits to two hospitals in the U.S. National Capitol Region. The result showed that agreement between chief complaint and discharge diagnosis was good overall, but substantial variability existed by syndrome.

2. Cochrane DH, Allegra JR, Rothman J. Comparison of physician's choice of charting template to ICD9 codes for biosurveillance using an emergency department electronic medical records database. Academic Emergency Medicine 2003; 10(5): 525. (Abstract)
   This abstract quantifies the level of agreement between physician's choice of charting template and ICD9 codes, and it showed that there was moderate to near perfect agreement for 8 of the 9 syndromes examined.

3. Espino, J.U., Wagner, M.M. Accuracy of ICD-9-coded chief complaints and diagnoses for the detection of acute respiratory illness. Proceedings AMIA Symposium 2001;:164-8. (http://dev.health.pitt.edu/ahrq/restricted/papers/AMIA2001_Jeremy_Espino.pdf)
   This study validates two detectors for acute respiratory illness, ICD-9-coded chief complaints and ICD-9-coded diagnoses, against the human classification of cases based on review of emergency department reports from the electronic medical record system. Using ICD-9-coded chief complaints, the sensitivity of detection of acute respiratory illness was 0.44 and its specificity was 0.97. The sensitivity and specificity using ICD-9-coded diagnoses were no different.

4. Dockrey MR, Trigg LJ, Lober WB. An information systems for 911 dispatch monitoring system and analysis. Proceeding of the AMIA 2002 Annual Symposium;: 1008. (Abstract)
   This conference abstract explores the utility of 911 calls as a potential data source for an early warning system.

5. Goldenberg A, Shmueli G, Caruana RA, Fienberg SE. Early statistical detection of anthrax outbreaks by tracking over-the-counter medication sales. Proceedings of the National Academy of Sciences of the United States of America 2002 Apr 16; 99(8): 5237-5240.
   This paper describes a statistical framework for monitoring grocery data to detect a large-scale but localized bioterrorism attack, and it also proposes an evaluation methodology that is suitable in the absence of data on large-scale bioterrorist attacks and disease outbreaks.

6. Graham J, Buckeridge D, Choy M, Musen M. Conceptual heterogeneity complicates automated syndromic surveillance for bioterrorism. Proceedings AMIA Symposium 2002;: 1030. (Abstract)

This conference abstract compared the case definitions for prodromes of illness due to biological weapons in 15 different syndromic surveillance systems, and they found substantial conceptual heterogeneity in the case definitions.

7. Greenko J, Mostashari F, Fine A, Layton M. Clinical Evaluation of the Emergency Medical Services (EMS) Ambulance Dispatch-Based Syndromic Surveillance System, New York City. Journal of Urban Health. 2003 Jun;80 Suppl 1:I50-I56.
   This paper describes a system that uses Emergency Medical Services (EMS) ambulance dispatch data to monitor for a communitywide rise in influenza-like illness (ILI) as an early detection system for bioterrorism, and it examines the potential bias involved in EMS data versus emergency department-based surveillance for ILI and determines the case sensitivity and predictive value positive of the selected EMS call types for ILI.

8. Hirshon JM. The rationale for developing public health surveillance systems based on emergency department data. Academic Emergency Medicine. 2000 Dec;7(12):1428-32.
   This article describes current concepts and status of emergency department surveillance systems, their advantages and disadvantages, the rationale for their existence, and recommendations to allow their continued consideration and development.

9. Ivanov O, Wagner MM, Chapman WW, Olszewski RT. Accuracy of three classifiers of acute gastrointestinal syndrome for syndromic surveillance. Proceedings AMIA Symposium 2002;:345-9.
   This study validates three classifiers for the detection of cases of acute gastrointestinal syndrome (one used ICD-9-coded emergency department diagnosis as input data; the other two used free-text triage diagnosis) against the expert classification of cases based on review of emergency department reports. The study concluded that the naïve Bayes classifier of free-text triage diagnosis data provides more sensitive and earlier detection of cases than either the bigram Bayes classifier or an ICD-9 code classifier.

10. Mocny M, Cochrane DG, Allegra JR, Nguyen T, Heffernan RT, Pavlin J, Rothman J. A comparison of two methods of biosurveillance of respiratory disease in the emergency department: chief complaint vs ICD9 diagnosis code. Academic Emergency Medicine 2003; 10 (5):513. (Abstract)
    This abstract compares two existing IC9 and chief complaint respiratory algorithms, to whether they identified the similar patients and patterns of illness when applied to the same ED database. Only fair agreements was observed due to the different information captured in the chief complaint and ICD9 and the different diagnostic targets included in the two algorithms.

11. Olson KL, Mandl K. Geocoding patient addresses for biosurveillance. Proceedings of the AMIA 2002 Annual Symposium;:1119. (Abstract)
    This conference abstract reports an analysis of two geocoding software packages on 3 years of emergency department visit data.

12. Tsui F, Wagner M, Dato V, Chang C. Value of ICD-9-Coded Chief Complaints for Detection of Epidemics. Proceedings AMIA Symposium 2001;:711-5. (http://dev.health.pitt.edu/ahrq/restricted/papers/AMIA01%20tsui.pdf)
    This study assesses the value of ICD-9-coded chief complaints for early detection of epidemics, the sensitivity, positive predictive value, and timeliness of Influenza detection using a respiratory set and Influenza set of ICD-9 codes.

13. Wagner MM, Aryel R, Dato VM, Krenzelok E, Fapohunda A, Sharma R. Availability and Comparative Value of Data Elements Required for an Effective Bioterrorism Detection System. 184 pages. Report commissioned by AHRQ. Delivered November 28, 2001 (Awaiting Publication). (http://www.health.pitt.edu/rods/AHRQInterimRpt112801.pdf)
    This report, commissioned by the Agency for Healthcare Research and Quality, addresses three related questions: (1) What data elements are required for an effective bioterrorism detection system; (2) What are their comparative values; and (3) What are their availability?

- **Analytic Modeling/Methods**

1. Buckeridge DL, Graham JK, O'Connor MJ, Choy MK, Tu SW, Musen MA. Knowledge-based bioterrorism surveillance. Proceedings AMIA Symposium 2002;:76-80. (http://smi-web.stanford.edu/projects/biostorm/bibliography/BuckeridgeAMIA2002.pdf)
    This paper presents an argument for knowledge-based surveillance, describes a prototype of BioSTORM, a system for real-time epidemic surveillance, and shows an initial evaluation of this system applied to a simulated epidemic from a bioterrorism attack.

2. Burkom HS. Biosurveillance applying scan statistics with multiple, disparate data sources. Journal of Urban Health. 2003 Jun;80 Suppl 1:I57-I65.
    This paper describes the application of scan statistics for early outbreak detection in Essence II, and extension of Essence I. Information was combined from disparate medical sources, including number of emergency room visits, outpatient visits, and insurance claims, and from non-medical sourvces such as counts of OTC remedy sales and school absenteeism.

3. Hutwagner L, Thompson W, Seeman GM, Treadwell T. The Bioterrorism Preparedness and Response Early Aberration Reporting System (EARS). Journal of Urban Health. 2003 Jun 1;80 Supplement 1:I89-I96.
    This paper describes the CDC Early Aberration Reporting System which allows the analysis of the public health surveillance data using available aberration detection methods. The primary purpose of EARS is to provide national, state, and local health departments with several alternative aberration detection methods for epidemiologic investigations.

4. Koch MW, McKenna SA. Near-real time surveillance against bioterror attack using space-time clustering 2001. [Accessed March 1, 2003]. (Technical Report) (http://www.cmc.sandia.gov/bio/rsvp/UNM_Bioterror_Report.pdf)

The technical report discusses the use of space-time clustering to detect bioterror attacks, and illustrate its use of detecting a flu epidemic with data collected by the French Sentinel Disease Network. Plans to extend space-time clustering to data collected for the Rapid Syndrome eValuation Project (RSVP) is also discussed.

5. McKenna SA. Development of a discrete spatial-temporal SEIR simulator for modeling infectious diseases. November 2000. [Accessed April 11, 2003]. (Technical Report) (http://www.cmc.sandia.gov/bio/rsvp/1_seir.pdf)

   This technical report examines the application of the SEIR model, which describes four discrete states of an epidemic (susceptible, exposed, infectious, and Recovered), to the spatial and temporal evolution of disease.

6. Moore A, Cooper G, Tsui R, Wagner M. Summary of biosurveillance-relevant technologies. [Accessed March 11, 2003] (Internet Report) (http://www-cgi.cs.cmu.edu/~awm/biosurv-methods.pdf)

   A short Internet report compiling the technologies used for biosurveillance by the Center for Biomedical Informatics, University of Pittsburgh. It indicates which analytic methods have been implemented and evaluated in different settings and the reasons they were selected for use in some situations.

7. Musen MA, O'Connor MJ, Buckeridge DL, Graham J, Noy NF, Shahar Y, Henry KA. A knowledge-based approach to temporal abstraction of clinical data for disease surveillance. [Accessed April 11, 2003]. (Internet Report) (http://www-smi.stanford.edu/pubs/SMI_Reports/SMI-2001-0891.pdf)

   This paper describes an automated method, known as the knowledge-based temporal abstraction method, for analysis of electronic patient-record data that uses medical knowledge to infer high-level patterns from primary data.

8. O'Brien SJ, Christie P. Do CuSums have a role in routine communicable disease surveillance? Public Health 1997 Jul; 111(4):255-8.

   This paper describes the CuSum technique, which allows rapid measurement of change from expected values based on historical data. CuSums represent a potentially useful adjunct to other surveillance methods in infection control.

9. Reis BY, Pagano M, Mandl KD. Using temporal context to improve biosurveillance. Proceedings of the National Academy of Sciences of the United States of America 2003 Feb 18; 100(4): 1961-5. (www.pnas.org/cgi/doi/10.1073/pnas.0335026100)

   The paper investigates the effectiveness of using multi-day temporal filters for detecting simulated outbreaks of varying shapes, magnitudes, and durations into 10 years of historical daily visit data from a major tertiary-care metropolitan teaching hospital. Their results show that compared with the standard 1-day approach, the multiday detection approach significantly increases detection sensitivity and decreases latency while maintaining a high specificity.

10. Reis BY, Mandl KD. Time series modeling for syndromic surveillance. BMC Medical Informatics and Decision Making 2003 Jan 23; 3(1): 2. (http://www.biomedcentral.com/1472-6947/3/2)
    Using time-series methods, the authors developed and tested robust models of emergency department utilization for the purpose of defining expected visit rates as well as the frequency of visits of patients with flu-like and respiratory illnesses. The models were based on nearly a decade of historical data at a major metropolitan academic, tertiary care pediatric emergency department.

11. Wagner, MM. Models of Computer-Based Outbreak Detection. Technical Report. October 2, 2000. [Accessed March 11, 2003]. (Technical Report – Under review) (http://dev.health.pitt.edu/ahrq/restricted/papers/models of computer-based outbreak detection.PDF)
    This paper describes a computational model, the inputs and outputs of a system and the algorithms required, of computer-based surveillance for detecting disease outbreaks.

12. Wong W, Moore A, Cooper G, Wagner M. Rule-Based Anomaly Pattern Detection for Detecting Disease Outbreaks. [Accessed March 11, 2003]. (http://www.autonlab.org/autonweb/documents/papers/wong-rule.pdf)
    This paper presents a rule-based algorithm for performing early detection of disease outbreaks by searching a database of emergency department cases for anomalous patterns. The algorithm is compared against a standard detection algorithm by using simulated data, and the algorithm had significantly better detection times for common significance thresholds while having a slightly higher false positive rate.

13. Wong W, Moore A, Cooper G, Wagner M. Rule-Based Anomaly Pattern Detection for Detecting Disease Outbreaks. Journal of Urban Health. 2003 Jun;80 Suppl 1:I66-I75.
    This paper presents a rule-based algorithm for performing early detection of disease outbreaks by searching a database of emergency department cases for anomalous patterns.

C. Informatics (Development and Implementation of Surveillance Systems)

- **Manual Information Systems: Require data abstraction or forms to be completed outside of the clinical work flow (both long-term and short-term)**

1. Arizona Department of Health Services. Syndromic Disease Surveillance in the Wake of Anthrax Threats and High Profile Public Events. Prevention, Publication of the Bureau of Epidemiology & Disease Control Services. January/February 2002, Vol. 16, No. 1. (http://www.scenpro.com/Press%20Release%2011%20Syndromic%20surveillance.pdf). (Newsletter)
   This newsletter article provides a brief synopsis of an enhanced surveillance project using aberration detection model, implemented in 15 emergency departments in Arizona during the study period of Oct 27-Nov 18, 2001.

2. County of Los Angeles, Department of Health Services, Acute Communicable Disease Control, Special Studies Report 2000. Democratic National Convention – Bioterrorism syndromic surveillance. [Accessed March 11, 2003]. (http://www.lapublichealth.org/acd/reports/spclrpts/spcrpt00/DemoNatConvtn00.pdf)
   This report describes a drop-in surveillance system for the Democratic National Convention held in Los Angeles in August 2000.

3. CDC/ MMWR. Syndromic surveillance for bioterrorism following the attacks on the World Trade Center. Sept 11, 2002/ 51 (Special issue); 13-15. (http://www.cdc.gov/mmwr/preview/mmwrhtml/mm51SPa5.htm)
   This report describes the operational and maintenance aspects of conducting syndromic surveillance for bioterrorism and demonstrates the limitations of drop-in systems that rely on manual data collection.

4. Das D, Weiss D, Mostashari F, Treadwell T, McQuiston J, Hutwagner L, Karpati A, Bornschlegel K, Seeman M, Turcios R, Terebuh P, Curtis R, Heffernan R, Balter S. Enhanced Drop-in Syndromic Surveillance in New York City Following September 11, 2001. Journal of Urban Health. 2003 Jun;80 Suppl 1:I76-I88.
   This report describes a drop-in emergency department syndromic surveillance system implemented in New York City from September 14 to October 12, 2001.

5. Jorm LR. Thackway SV, Churches TR, Hills MW. Watching the Games: public health surveillance for the Sydney 2000 Olympic Games. J Epidemiol Community Health. 2003 Feb;57(2):102-8.
   This paper describes the development of the public health surveillance system for the Sydney 2000 Olympic Games; document its major findings; and discuss the implications for public health surveillance for future events.

6. Moran GJ, Talan DA. Update on emerging infections: news from the Centers for Disease Control and Prevention. Annals of Emergency Medicine 2003; 41(3): 414-418.
   This update, provided by the CDC and EMERGEncy ID net, reports the implementation of an emergency department-based syndromic surveillance system following the attacks on the World Trade Center – New York City, 2001.

7. Osaka K, Takahashi H, Ohyama T. Testing a symptom-based surveillance system at high-profile gatherings as a preparatory measure for bioterrorism. Epidemiol Infect 2002 Dec; 129(30): 429-34.
   This paper describes a project testing symptom-based surveillance during the G8 conference in 2000 as a means of detecting outbreaks, including bio-terrorism attacks, promptly. The performance of the system was compared to a pre-existing national epidemiological surveillance of infectious disease.

8. Talan DA, Moran GJ, Mower WR, Newdow M, Ong S, Slutsker L, Jarvis WR, Conn LA, Pinner RW. EMERGEncy ID NET: an emergency department-based emerging infections sentinel network. Clin Infect Dis 1999 Feb;28(2):401-2.

This article describes the background, development, and implementation of EMERGEncy ID NET, an interdisciplinary, multicenter, ED-based network for research of emerging infectious diseases. Data are collected during ED evaluation of patient with specific clinical syndromes, and are electronically stored, transferred, and analyzed at a central receiving center.

9. Zelicoff A, Brillman J, Forslund DW, George JE, Zink S, Koenig S, Staab T, Simpson G, Umland E, Bersell K. The Rapid Syndrome Validation Project. Proceedings AMIA Symposium 2001; 771-5.
   The paper describes the purpose and the architecture of Rapid Syndrome Validation Project, a network-based surveillance system, which is currently being implemented in an Emergency Department.

- **Automatic Information Systems: Surveillance system analyzing medical database for aberrations; possibly long-term**

1. Irvin CB, Nouhan PP, Rice K. Syndromic analysis of computerized emergency department patients' chief complaints: an opportunity of bioterrorism and influenza surveillance. Annals of Emergency Medicine 2003; 41(4): 447-452.
   This paper describes a web-based surveillance system that analyzes computerized emergency department patient's chief complaints for syndromes related to terrorism and sends an alert e-mail message when an outbreak is detected.

2. Gesteland PH, Wagner MM, Chapman WW, Espino JU, Tsui F, Gardner RM, Rolfs RT, Dato V, James BC, Huang PJ. Rapid deployment of an electronic disease surveillance system in the state of Utah for the 2002 Olympic winter games. Proceedings AMIA Symposium 2002;: 285-9.
   This paper details the experience of deploying the Real-time Outbreak and Disease Surveillance (RODS) system in Utah during a 28-day period spanning the 2002 Olympic winter games. The paper addresses health system and health department concerns, data sharing agreements, project management, implementation, and public health integration.

3. Lazarus R, Kleinman K, Dashevsky I, Adams C, Kludt P, DeMaria A Jr, Platt R. Use of automated ambulatory-care encounter records for detection of acute illness clusters, including potential bioterrorism events. Emerging Infectious Disease 2002 Aug; 8(8): 753-60.
   This paper describes an automated system that produces information within 24 hours about illness clusters, based on ambulatory-care visits and telephone calls. This system complements emergency room and hospital-based surveillance by adding the capacity to rapidly identify cluster of illness, including potential bioterrorism events.

4. Lazarus R, Kleinman KP, Dashevsky I, DeMaria A., Platt R. Using automated medical records for rapid identification of illness syndromes (syndromic surveillance): the example of lower respiratory infection. BMC Public Health 2001; 1(1): 9.
   (http://www.biomedcentral.com/1471-2458/1/9)

This paper describes some of the technical and methodological issues encountered in developing a surveillance system for lower respiratory infection based on automated ambulatory care electronic encounter records from a large HMO and multi-specialty group practice.

5. Lewis M, Pavlin J, Mansfield J, O'Brien S, Boomsma L, Elbert Y, Kelley P. Disease outbreak detection system using syndromic data in the greater Washington DC area. American Journal of Preventive Medicine 2002; 23(3) 180-186. (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VHT-46T9D7X-6&_coverDate=10%2F31%2F2002&_alid=86644084&_rdoc=1&_fmt=&_orig=search&_qd=1&_cdi=6075&_sort=d&view=c&_acct=C000046148&_version=1&_urlVersion=0&_userid=856389&md5=c81b95d2cee45e3a34db58929a5508e3)

   This paper describes the implementation of the centralized Department of Defense medical information systems, ESSENCE, in detecting outbreaks diagnoses based on ICD-9-CM codes obtained daily from 99 military emergency rooms and primary care clinics across the Washington, DC region from December 1999 to January 2002.

6. Lober WB, Trigg LJ, Karras BT, Bliss D, Ciliberti J, Stewart L, Duchin JS. Syndromic surveillance for bioterrorism using automated collection of computerized discharge diagnoses. Journal of Urban Health. 2003 Jun; 80 Suppl 1:I97-I106. (Additional information located at http://cirg.washington.edu/public/cirg/ssic.php)

   This article describes the Syndromic Surveillance Information Collection system, in place since June 2001, that collects, integrates, and displays data from emergency department and urgent care departments and primary care clinics by automatically mining data from the information systems of those facilities.

7. Lombardo J, Burkom H, Elbert E, Magruder S, Lewis SH, Loschen W, Sari J, Sniegoski C, Wojcik R, Pavlin J. A Systems Overview of the Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE II). J Urban Health 2003; 80: i32-i42.

   This paper describes the system, data sources, electronic data collection and formatting, detection, internet-based information distribution, and evaluation of performance of ESSENCE II, an electronic surveillance system that uses syndromic and nontraditional health information to provide early warning of abnormal health conditions in the National Capital Area.

8. RODS Demonstration Systems in Public Health Surveillance: Completed, Ongoing, and Planned. July 1, 2002. [Accessed March 11, 2003]. (Technical Report) (http://www.health.pitt.edu/rods/RODS%20Demonstration%20Systems6.pdf)

   This report summarizes the goals and results of RODS projects—completed, ongoing, and planned.

9. Tsui FC, Espino JU, Wagner MM, Gesteland P, Ivanov O, Olszewski R, Liu Z, Zeng X, Chapman WW, Wong WK, Moore AW. Data, Network, and Application: Technical Description of the Utah RODS Winter Olympic Biosurveillance System. Proceedings AMIA Symposium 2002;: 815-9.

This paper describes the technical parts at the data, network, and application level of Utah RODS used to remotely monitor the health status of Utah from the University of Pittsburgh during the 2002 Winter Olympics.

D. Syndromic Surveillance Information Systems (Internet websites)

- **Manual Information Systems**

1. **Enhanced Consequence Management Planning and Support System** (ENCOMPASS) (http://www.darpa.mil/DSO/trans/pdf/encompass.pdf) is a computer-based program that assists in disaster and patient information management. It provides incident commanders and first responders with a common operational picture of the scene including fast-time updates, location and identification of resources and personnel, and a situational analysis.

2. **Lightweight Epidemiological Advanced Detection Emergency Response System (LEADERS)** (http://www.scenpro.com/) provides immediate, web-based exchange of critical medical monitoring and incident response information among participating organizations.

3. **Rapid Syndrome Validation Project (RSVP)** (http://www.cmc.sandia.gov/bio/rsvp/) is a real-time, full-time medical database that is used to track and report and outbreaks of syndromes - signs and symptoms - rather than positive diagnoses of specific diseases. RSVP is able to displaying syndromic information geographically and temporally.

- **Automatic Information Systems**

1. **Biological Spatio-Temporal Outbreak Reasoning Module (BioSTORM)** (http://smi-web.stanford.edu/projects/biostorm/) is a research program to develop and evaluate intelligent systems for epidemic detection and characterization.

2. **Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE)** (http://www.geis.ha.osd.mil/GEIS/SurveillanceActivities/ESSENCE/ESSENCE.asp) has been based on downloading Ambulatory Data System (ADS) diagnoses from 104 primary care and emergency clinics within a 50-mile radius of Washington, DC. The diagnostic codes are grouped into "syndromic clusters" consistent with emerging infections including bioterrorism.

3. **Rapidly Deployable Surveillance System (RDSS)** (http://www-nehc.med.navy.mil/hp/pophealth/RDSS.htm) developed by Navy Environmental Health Center enables Navy MTFs to quickly establish a syndromic surveillance system for acute infection diseases that could potentially be caused by a biological warfare agents.

4. **Real-time Outbreak and Disease Surveillance (RODS)** (http://www.health.pitt.edu/rods/) is a real-time computer-based public health surveillance system developed to monitor a population within a geographic region. To this end, RODS can automatically collect and

store de-identified emergency department (ED) registration data from hospitals within the region under surveillance, analyzes the data for deviations from expected levels, and displays the results for interpretation by public health officials.

E. Surveillance Evaluation

1. CDC. Draft framework for evaluating syndromic surveillance systems for bioterrorism preparedness. [Accessed August 14, 2003] (http://www.cdc.gov/epo/dphsi/syndromic/framework.htm).
   This report expands on previous guidelines for evaluating public health surveillance systems, emphasizing timeliness for outbreak detection and dissecting the relationship between sensitivity and predictive value as critical attributes. Though the framework is best handled with actual data to demonstrate the attributes of the system, the framework can also be applied to systems that are in early stages of development or in the planning phase.

2. Karras BT, Lober WB, Smith GT. Evaluating the new electronic disease surveillance systems. University of Washington School of Public Health & Community Medicine 2002 Fall/Winter; 22-23. (http://healthlinks.washington.edu/nwcphp/nph/f2002/surveillance_f2002.pdf)
   This article outlines 10 points for public health professionals t consider when making decisions about the utility of new electronic surveillance systems. These points are categorized under vendor, validation, flexibility, expandability, operation/ timeliness/ reliability, notification, usability, security, compatibility, and supportability.

3. Lenaway DD, Ambler A. Evaluation of a school-based influenza surveillance system. Public Health Reports 1995 May-June; 110(3): 333-337.
   The Boulder-County Health Department, CO developed, piloted, and implemented a school-based surveillance system in 1988. Using the CDC guidelines for evaluation surveillance systems, the system was evaluated against a preexisting communicable disease sentinel surveillance system.

4. Mostashari F, Fine A, Das D, Adams J, Layton M. Use of ambulance dispatch data as an early warning system for communitywide influenza like illness, New York city. Journal of Urban Health. 2003 Jun;80 Suppl 1:I43-I49.
   This article describes an evaluation of a surveillance methodology based on electronic records of ambulance dispatches to detect communitywide respiratory outbreaks.

5. Sosin, DM. Draft framework for evaluating syndromic surveillance systems. Journal of Urban Health 2003; 80(2): i8-i13.
   This paper highlights the CDC draft framework for evaluating syndromic surveillance systems for bioterrorism preparedness.

6. Suyama J, Sztajnkrycer M, Lindsell C, Otten EJ, Daniels JM, Kressel AB. Surveillance of Infectious Disease Occurrences in the Community: An Analysis of Symptom Presentation in the Emergency Department. Academic Emergency Medicine 2003 Jul;10 (7):753-63.

The purpose of the study was to assess the ability of a simulated syndromic surveillance system in the emergency department (ED) setting to predict infectious disease trends in the community by comparing frequency changes of symptom presentation in the ED with known cases of class A diseases identified by public health officials over a two-year period.

F. Additional Resources

1. Barthell EN, Cordell WH, Moorhead JC, Handler J, Feied C, Smith MS, Cochrane DG, Felton CW, Collins MA. The Frontlines of Medicine Project: a proposal for the standardized communication of emergency department data for public health uses including syndromic surveillance for biological and chemical terrorism. Annals of Emergency Medicine 2002 Apr; 39(4):422-9.
   The Frontlines of Medicine Project proposes to develop a nonproprietary, "open systems" approach for reporting emergency department patient data. The common element is a standard approach to sending messages from individual emergency departments to regional oversight entities that could then analyze the data received.

2. Broome C, Horton H, Tress D, Lucido SJ, Koo D. Statutory basis for public health reporting beyond specific diseases. Journal of Urban Health 2003; 80: i14-i22.
   This article provides specific information about the general disease reporting provisions in each state and also shows that the intent of these reporting laws and the HIPAA privacy rule is to support the critical disease surveillance function for the benefit of the population.

3. CDC Syndromic Surveillance WebBoard. A communication forum to exchange and share information regarding outbreak detection and syndromic surveillance. (http://syndromic.forum.cdc.gov/)

4. Kaufmann AF, Meltzer MI, Schmid GP. The economic impact of a bioterrorist attack: are prevention and postattack intervention programs justifiable? Emerging Infectious Diseases 1997. 3(2): 83-94.
   This paper constructs a model that shows the economic impact of a bioterrorist attack. By using an insurance analogy, the model provides economic justification for preparedness measures.

5. Lopez W. New York City and State Legal Authorities Related to Syndromic Surveillance. Journal of Urban Health 2003; 80: i23-i24.
   This article describes the legal authority of New York City and State for conducting surveillance of syndromes of illness and disease that may be indicative of outbreaks or of unusual manifestations of disease in an individual.

6. Rodriguez VA, Silverman ME, Cochrane DG, Allegra JR, Eskin B, Rothman J. Influence of age and seasonality in an emergency department biosurveillance system. Academic Emergency Medicine 2003; 10(5): 460. (Abstract)

This abstract characterized the seasonality of gastroenteritis (GE) over a longer period of time and to determine the contribution of children age <60 to the pattern. The abstract concluded that there are consistent seasonal GE peaks over the entire 15 year period, and the younger age group contributed disproportionately to the GE observed.

7. National Syndromic Surveillance Conference. September 23rd - 24th, 2002 · New York, New York. (http://www.nyam.org/events/syndromicconference/2002)

G. Non-BT related resources

1. Brinsfield KH, Bunn JE, Barry MA, McKenna V, Dyer KS, Sulis C. Using volume-based surveillance for an outbreak early warning system. Academic Emergency Medicine 2001; 8: 492. (Abstract)
   This abstract determined whether volume-based surveillance of emergency departments (EDs) and urgent care centers (UCCs) can provide early warning of an outbreak. The abstract concludes that increases in UCC and adult ED volume correlate with influenza isolation and that volume-based surveillance may be used for mass casualty events.

2. Frisen M. Statistical surveillance: optimality and methods. (Awaiting publication)
   This paper presents an overview of commonly used statistical methods, with respect to optimality, for surveillance within a number of disciplines.

3. Harcourt SE, Smith GE, Hollyoak V, Joseph CA, Chaloner R, Rehman Y, Warburton F, Ejidokin, Watson JM, Griffiths RK. Can calls to NHS Direct be used for syndromic surveillance? Commun Dis Public Health 2001; 4: 178-88.
   This study assessed whether NHS Direct, a national nurse-led telephone advice line in England, could be a useful source of surveillance data for communicable diseases, using influenza as a pilot condition.

4. Hutwagner LC, Maloney EK, Bean NH, Slutsker L, Martin SM. Using laboratory-based surveillance data for prevention: an algorithm for detecting Salmonella outbreaks. Emerging Infectious Diseases 1997. 3(3): 395-400.
   The authors developed a computer algorithm, applying the CUSUM method, to identify outbreaks of Salmonella Enteritidis isolates in 1993. By comparing these detected outbreaks with known reported outbreaks, they estimated the sensitivity, specificity, and false-positive rates.

5. Kaninda AV, Belanger F, Lewis R, Batchassi E, Aplogan A, Yakoua Y, Paquet C. Effectiveness of incidence thresholds for detection and control of meningococcal meningitis epidemics in northern Togo. International Journal of Epidemiology. 2000 Oct;29(5):933-40.
   This paper describes a study to assess the validity of currently recommended threshold and studies other thresholds that might allow an earlier detection of meningococcal meningitis epidemics and thereby increase the impact of reactive mass vaccination campaigns.

6. Lewis R, Nathan N, Diarra L, Belanger F, Paquet C. Timely detection of meningococcal meningitis epidemics in Africa. Lancet. 2001 Jul 28;358(9278):287-93.
   The paper describes a study to assess the ability of meningitis incidence thresholds to detect epidemics in time to intervene effectively, according to the epidemiological context and completeness of case-reporting, and to explore prediction of meningitis epidemics, in areas with less than 30,000 inhabitants in Mali.

7. Moore PS, Plikaytis BD, Bolan GA, Oxtoby MJ, Yada A, Zoubga A, Reingold AL, Broome CV. Detection of meningitis epidemics in Africa: a population-based analysis. International Journal Epidemiology. 1992 Feb;21(1):155-62.
   The paper evaluates the usefulness of weekly meningitis rates derived from active surveillance data in Burkina Faso for detecting a meningitis epidemic.

8. Proctor ME, Blair KA, Davis JP. Surveillance data for waterborne illness detection: and assessment following a massive waterborne outbreak of Cryptosporidium infection. Epidemiol Infect 1998; 120: 43-54.
   The authors examine surveillance data from eight non-traditional sources and summarize the relative strengths and weaknesses of these data and related methods for routine community-wide waterborne illness detection and their application in outbreak decision-making.

9. Quenal P, Dab W, Hannoun C, Cohen JM. Sensitivity, specificity and predictive values of health service based indicators for the surveillance of influenza A epidemics. International Journal of Epidemiology 1994; 23(4): 849-855.
   This study assesses the predictive value of health service based indicators for the detection of influenza A epidemics and validated the indicators against lab confirmed influenza. Indicators included medial activity, absenteeism from work, drug consumption, and hospital activity. The results of the study showed that the indicators were easy to collect and are useful for the surveillance of influenza epidemics.

10. Rodman JS, Frost F, Jakubowski W. Using nurse hot line calls for disease surveillance. Emerg Infect Dis 1998 Apr-Jun; 4(2):329-32.
   In this study, nurse hot line data from Milwaukee, Wisconsin, showed more than a 17-fold increase in calls for diarrhea during the 1993 Milwaukee cryptosporidiosis outbreak. Moreover, consistent patterns of seasonal variation in diarrhea- and vomiting-related calls were detected from the Baltimore, Maryland, and Albuquerque, New Mexico, hot lines. Analysis of nurse hot line calls may provide an inexpensive and timely method for improving disease surveillance.

11. Tappero JW, Khan AS, Pinner RW, Wenger JD, Graber JM, Armstrong LR, Holman RC, Ksiazek TG, Khabbaz RF. Utility of emergency, telephone-based national surveillance for Hantavirus pulmonary syndrome. JAMA 1996; 275 (5): 398-400.
   This paper focuses on a toll-free telephone hotline, instituted to provide updated information about unexplained respiratory illness and to serve as a passive mechanism for reporting suspected cases. This passive surveillance system was successful in rapidly

identifying the widespread sporadic geographic distribution for Hantavirus pulmonary syndrome through the US and could serve as a model for similar emergencies.

12. Toubiana L, Flahault A. A space-time criterion for early detection of epidemics of influenza-like-illness. European Journal of Epidemiology 1998; 14: 465-470.
    The authors developed a method based on a space-time criterion for the early detection of epidemics of influenza-like illness, and they applied this algorithm to the last 11 epidemics (from 1986), resulting in good sensitivity and specificity.

13. Welliver RC, Cherry JD, Boyer KM, Deseda-Tous JE, Krause PJ, Dudley JP, Murray RA, Wingert W, Champion JG, Freeman G. Sales of nonprescription cold remedies: a unique method of influenza surveillance. Pediat. Res. 1979; 13: 1015-1017.
    In this paper, in addition to reporting the influenza surveillance findings of Los Angeles, sales of nonprescription cold remedies in a large supermarket chain were evaluated as an indicator of influenza activity in the community. The data suggest that monitoring sales of nonprescription cold remedies may be a useful technique of influenza surveillance, especially in years when minimal activity occurs.